IC 9:

Gait Analysis at your Fingertips: Enhancing Observational Gait Analysis using Mobile Device Technology and the Edinburgh Visual Gait Scale

Jon R. Davids, MD
Vedant A. Kulkarni, MD
Suzanne Bratkovich, PT

Shriners Hospitals for Children – Northern California / University of California, Davis
Sacramento, CA USA

Full course material can be downloaded from: www.shrinerschildrens.org/aacpdm2017
IC 9: Course Outline

- Introduction to Normal Gait
- Introduction to the Edinburgh Visual Gait Scale.
- Mobile Device Videography and App-Based Analysis
- Break: (10 minutes)
- Case-Based Audience Participation: Case examples for analysis of gait using mobile device technology and the Edinburgh Visual Gait Scale.
- Questions / Discussion
NORMAL GAIT AND IDENTIFICATION OF COMMON GAIT DEVIATIONS IN CHILDREN WITH CEREBRAL PALSY

I. Normal Gait
   A. The Gait Cycle

   B. Stance Phase
      1. Loading Response
      2. Mid Stance
      3. Terminal Stance
      4. Pre-Swing

   C. Swing Phase
      1. Initial Swing
      2. Mid Swing
      3. Terminal Swing

   D. Biomechanics
      1. Balance of Forces
         a. External Forces
            (1) Stance Phase: Ground Reaction Force
(2) Swing Phase: Gravitational, Inertial Forces

b. Internal Forces
   (1) Muscles
   (2) Ligaments / Joint Capsule
   (3) Skeletal Anatomy

2. Location of Ground Reaction Force to Joint Centers
   a. Controlled by
      (1) Muscle Activity
      (2) Body Segmental Alignment

E. Pre-requisites of Normal Gait
   1. Stability in Stance
   2. Clearance in Swing
   3. Effective Phase Shifts
      a. Stance to Swing / Swing to Stance
   4. Energy Efficiency

F. Terminology at the Ankle / Foot
   1. First / Heel Rocker
      a. Loading Response
   2. Second / Ankle Rocker
      a. Mid Stance
   3. Third / Forefoot Rocker
      a. Terminal Stance / Pre-Swing

II. Gait Disruption in Children with Cerebral Palsy

A. Task Analysis
   1. Propulsion
a. Temporo-spatial Parameters

2. Stability in Stance
   a. Shock Absorption
   b. Single Support

3. Clearance in Swing
   a. Peak Knee Flexion

4. Effective Phase Shifts
   a. Stance to Swing
      (1) Power Generation
   b. Swing to Stance
      (1) Terminal Swing Alignment

5. Energy Efficiency
   a. Increased Passenger Segment Deviations
   b. Increased Use of “Active” Stabilization Mechanisms
   c. Decreased Limb Segment Coordination
   d. Biarticular Muscle Dysfunction

III. Classification of Gait Deviations

A. Primary Deviations / Deficits
   1. Directly Related to Underlying Pathology (Spasticity)

B. Secondary Deviations / Deficits
   1. Related to Growth and Development
      (Muscle Contracture, Skeletal Malalignment)

C. Tertiary Deviations / Deficits
   1. Obligatory, Detrimental (Knee Hyperextension)
   2. Obligatory / Voluntary, Helpful (Forward Trunk Lean)
D. Interventions

1. Address Primary Deviations / Deficits (Neurosurgery, Pharmacologic)
2. Address Secondary Deviations / Deficits (Musculoskeletal Surgery)
3. Tertiary Deviations / Deficits (Resolve Spontaneously)

IV. Common Gait Deviations

A. Common Deviations at the Hip

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Gait Cycle</th>
<th>Cause</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limited Flexion</td>
<td>Initial Contact / Loading Response</td>
<td>- Compensation for weak hip extensor muscle group</td>
<td>• Decreased shock absorption</td>
</tr>
<tr>
<td>Pre-swing</td>
<td></td>
<td>- Weak hip flexor muscle group</td>
<td>• Diminished knee flexion in Swing</td>
</tr>
<tr>
<td>Mid-swing</td>
<td></td>
<td>- Weak hip flexor muscle group</td>
<td>• Poor foot clearance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Impaired motor control</td>
<td>• Poor foot position for initial contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hip pain</td>
<td></td>
</tr>
<tr>
<td>Excess Flexion</td>
<td>Initial Contact / Loading Response</td>
<td>- Spasticity / Contracture of hip flexor muscle group</td>
<td>• Increased demand on knee and hip extensor muscle groups</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Compensation for excess knee flexion / ankle dorsiflexion</td>
<td>• Decreased limb stability</td>
</tr>
<tr>
<td>Mid-swing</td>
<td></td>
<td>• Compensation for diminished knee flexion / ankle dorsiflexion</td>
<td>• Helps clearance</td>
</tr>
<tr>
<td>Internal Rotation</td>
<td>Mid-stance</td>
<td>- Increased femoral anteverision</td>
<td>• Intoeing gait pattern</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Compensation for external pelvic rotation</td>
<td>• Impaired forward progression</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Disrupts patellofemoral tracking</td>
<td></td>
</tr>
<tr>
<td>External Rotation</td>
<td>Mid-stance</td>
<td>- Diminished femoral anteverision</td>
<td>• Outtoeing gait pattern</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Increased thigh girth</td>
<td>• Increased base of support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Compensation for knee / ankle / foot pain</td>
<td>• Decreased foot lever arm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Excess loading of medial knee and ankle ligaments</td>
</tr>
<tr>
<td>Stage</td>
<td>Phase</td>
<td>Details</td>
<td>Consequences</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mid-swing</td>
<td></td>
<td>• Compensation for weak hip flexor muscle group</td>
<td>• Helps clearance</td>
</tr>
<tr>
<td>Adduction</td>
<td>Mid-stance</td>
<td>• Adductor muscle group spasticity</td>
<td>• Decreased base of support</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Secondary to weak hip abductor muscle group (contralateral pelvic drop)</td>
<td>• Decreased limb stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Apparent (combination of hip flexion and internal rotation)</td>
<td>• Functional lengthening of reference limb</td>
</tr>
<tr>
<td>Abduction</td>
<td>Mid-stance</td>
<td>• Compensation for long reference limb</td>
<td>• Increased base of support</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Functional shortening of reference limb</td>
</tr>
<tr>
<td>Mid-swing</td>
<td></td>
<td>• Compensation for long reference limb</td>
<td>• Functional shortening of reference limb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Compensation for weak hip flexor muscle group</td>
<td>• Helps reference limb advancement in Swing</td>
</tr>
</tbody>
</table>
### B. Common Deviations at the Knee

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Gait Cycle</th>
<th>Cause</th>
<th>Significance</th>
</tr>
</thead>
</table>
| Limited flexion    | Initial Contact / Loading Response | • Weak knee extensor muscle group  
• Knee pain  
• Impaired proprioception | • Decreased shock absorption                   |
|                    | Mid-swing                   | • Secondary to poor hip flexor function  
• Rectus femoris spasticity  
• Knee pain | • Poor foot clearance  
• Poor foot position for initial contact |
| Excessive Flexion  | Initial Contact / Loading Response | • Knee flexion spasticity/contracture  
• Impaired proprioception | • Decreased shock absorption                   |
|                    | Mid-stance                  | • Knee flexion spasticity/contracture  
• Impaired proprioception | • Increased demand on knee extensor muscle group  
• Decreased stability |
|                    | Terminal Swing              | • Knee flexion spasticity/contracture  
• Impaired proprioception | • Poor foot position for initial contact       |
| Hyperextension     | Mid-stance                  | • Secondary to excessive ankle plantar flexion  
• Impaired proprioception  
• Intentional to increase limb stability | • Decreased forward progression  
• Damage to knee ligaments |
C. Common Deviations at the Ankle / Foot

<table>
<thead>
<tr>
<th>Deviation</th>
<th>Gait Cycle</th>
<th>Possible Causes</th>
<th>Significance</th>
</tr>
</thead>
</table>
| Toe Strike                       | Initial Contact        | • Inadequate knee extension in TSw  
• Inadequate ankle dorsiflexion in TSw 
• Compensation for knee extensor weakness  
• Hindfoot pain                     | • Loss of first rocker  
• Disruption of forward momentum  
• Diminished shock absorption |
| Foot Slap                        | Loading Response       | • Weak ankle dorsiflexor muscles                                                                                                   | • Disruption of forward momentum  
• Diminished shock absorption |
| Excessive Plantar Flexion (Toe-walking) | Mid-stance            | • Plantar flexor muscle group spasticity / contracture  
• Compensation for knee extensor weakness  
• Ankle pain                           | • Disrupted second rocker |
| Excessive Plantar Flexion (Foot Drag) | Mid-swing / Terminal Swing | • Weak dorsi-flexor muscles  
• Plantar flexor muscle group spasticity / contracture  
• Limited voluntary motor control of dorsi-flexor muscle group                  | • Poor foot clearance  
• Poor foot position for subsequent initial contact |
| Early Heel Rise (Vaulting)       | Mid-stance             | • Compensation for long (anatomic or functional) contralateral limb in swing phase                                                  | • Overload of ankle plantar flexor muscle group |
| Delayed/Absent Heel Rise         | Terminal Stance        | • Weak ankle plantar flexor muscles  
• Mid-/Forefoot pain                 | • Disrupted third rocker  
• Decreased step/stride length       |
| In-toeing                        | Mid-stance             | • Internal pelvic rotation  
• Increased femoral anteversion  
• Internal tibial torsion  
• Varus foot malalignment           | • Disruption of forward progression |
<p>|                                 | Mid-swing              | • Internal pelvic rotation                                                        | • Poor foot                      |</p>
<table>
<thead>
<tr>
<th>Stance Phase</th>
<th>Conditions</th>
<th>Description</th>
</tr>
</thead>
</table>
| Out-toeing   | - Increased femoral anteversion  
              - Internal tibial torsion  
              - Varus foot malalignment | clearance (hitting against opposite limb)        |
| Mid-stance   | - External pelvic rotation  
              - Diminished femoral anteversion  
              - External tibial torsion  
              - Valgus foot malalignment | - Diminished stability                           |
| Terminal Stance | - External pelvic rotation  
                   - Diminished femoral anteversion  
                   - External tibial torsion  
                   - Valgus foot malalignment | - Disrupted third rocker                        |
References1-15


Mobile Device Videography and App-Based Analysis

• Principles of Gait Video Acquisition
  – Focus & Lighting
  – Proper Perspective
  – Subject clothing for Optimal Visualization
  – Skin Marking for Enhanced Landmark Visualization
  – Tracking the Subject
  – Minimizing Motion Artifact

• Low Cost Options for Mobile Videography
  – Hand-held
  – Selfie Stick
  – Gimbal

• Video Editing Options - Free and Low Cost Options
  – Built-in Video Editor on Device (free)
  – **Huddl Technique (free)**
  – Slowmo – Slow Motion Video Analysis (free)
  – Coach’s Eye – Video Analysis ($4.99)
  – Dartfish Express ($6.99)
Video-Based Gait Analysis using *Huddl Technique*

*Huddl Technique: Slow Motion Video Analysis*
UberSense Inc
Offers In-App Purchases

*Ehentials*

*OPEN*

Offers Apple Watch App

Details Reviews Related

*OPEN*

Download App from Apple App Store or Google Play
EVGS Scoring Worksheet

Terminal Swing/Initial Contact R

Peak Hip Flexion (EVGS #13)
- Markedly increased flexn (>60°)  2
- Increased flexn (46°-60°)  1
- Normal flexn (25°-45°)  0
- Reduced flexn (10°-24°)  1
- Severely reduced flexn (<10°)  2

Knee Position (EVGS #10)
- Severe flexn (>30°)  2
- Moderate flexn (16°-30°)  1
- Normal flexn (5°-15°)  0
- Moderate extn (4° flexn - 10 extn)  1
- Severe hyperextn (>10° extn)  2

Foot Position (EVGS #1)
- Heel Contact  0
- Flatfoot Contact  1
- Toe Contact  2

Terminal Swing/Initial Contact L

Peak Hip Flexion (EVGS #13)
- Markedly increased flexn (>60°)  2
- Increased flexn (46°-60°)  1
- Normal flexn (25°-45°)  0
- Reduced flexn (10°-24°)  1
- Severely reduced flexn (<10°)  2

Knee Position (EVGS #10)
- Severe flexn (>30°)  2
- Moderate flexn (16°-30°)  1
- Normal flexn (5°-15°)  0
- Moderate extn (4° flexn - 10 extn)  1
- Severe hyperextn (>10° extn)  2

Foot Position (EVGS #1)
- Heel Contact  0
- Flatfoot Contact  1
- Toe Contact  2
EVGS Scoring Worksheet

Mid-Stance Right

Peak Sagittal Position of Trunk in Stance (EVGS #16)
- Normal (vertical to 5° fwd or bkwd) 0
- Moderate (> 5° bkwd or 6° - 15° fwd) 1
- Marked (> 15° fwd lean) 2

Pelvic Rotation Mid-Stance (EVGS #15)
- Marked retraction (> 15°) 2
- Mod retraction (6° - 15°) 1
- Normal (5° retr - 10° pro) 0
- Mod protraction (11° - 20°) 1
- Marked protraction (> 20°) 2

Heel Lift in Stance (EVGS #2)
- No forefoot contact 2
- Delayed (with or after contralat foot contact) 1
- Normal (between contralat foot level and IC) 0
- Early (before opp foot level) 1
- No heel contact 2

Mid-Stance Left

Peak Sagittal Position of Trunk in Stance (EVGS #16)
- Normal (vertical to 5° fwd or bkwd) 0
- Moderate (> 5° bkwd or 6° - 15° fwd) 1
- Marked (> 15° fwd lean) 2

Pelvic Rotation Mid-Stance (EVGS #15)
- Marked retraction (> 15°) 2
- Mod retraction (6° - 15°) 1
- Normal (5° retr - 10° pro) 0
- Mod protraction (11° - 20°) 1
- Marked protraction (> 20°) 2

Heel Lift in Stance (EVGS #2)
- No forefoot contact 2
- Delayed (with or after contralat foot contact) 1
- Normal (between contralat foot level and IC) 0
- Early (before opp foot level) 1
- No heel contact 2
EVGS Scoring Worksheet

Terminal Stance R

Peak Hip Extension in Stance (EVGS #12)
- Severe flxn (>15°) 2
- Moderate flxn (1° -15°) 1
- Normal (0° -20° extn) 0
- Mod hyperextn (21° -35°) 1
- Severe hyperextn (> 35°) 2

Peak Knee Extension in Stance (EVGS #9)
- Severe flxn (>25°) 2
- Mod flxn (16° – 25°) 1
- Normal (0° - 15° flxn) 0
- Moderate hyperextn (1° - 10°) 1
- Severe hyperextn (>10°) 2

Max Ankle Dorsiflexion in Stance (EVGS # 3)
- Excessive df (>40°) 2
- Increased df (26° - 40°) 1
- Normal (5° - 25° df) 0
- Reduced df (10° pf - 4° df) 1
- Marked pf (>10°) 2

Terminal Stance L

Peak Hip Extension in Stance (EVGS #12)
- Severe flxn (>15°) 2
- Moderate flxn (1° -15°) 1
- Normal (0° -20° extn) 0
- Mod hyperextn (21° -35°) 1
- Severe hyperextn (> 35°) 2

Peak Knee Extension in Stance (EVGS #9)
- Severe flxn (>25°) 2
- Mod flxn (16° – 25°) 1
- Normal (0° - 15° flxn) 0
- Moderate hyperextn (1° - 10°) 1
- Severe hyperextn (>10°) 2

Max Ankle Dorsiflexion in Stance (EVGS # 3)
- Excessive df (>40°) 2
- Increased df (26° - 40°) 1
- Normal (5° - 25° df) 0
- Reduced df (10° pf - 4° df) 1
- Marked pf (>10°) 2
### EVGS Scoring Worksheet

#### Mid-Swing R

**Peak Knee Flexion in Swing (EVGS #11)**
- Severely increased (>85° flxn) 2
- Mod increased (71° -85° flxn) 1
- Normal flxn (50° -70°) 0
- Mod reduced (35° -49° flxn) 1
- Severely reduced (<35° flxn) 2

**Maximum Ankle Dorsiflexion in Swing (EVGS #7)**
- Excessive df (>30° df) 2
- Increased df (16° -30° df) 1
- Normal (15° df – 5° pf) 0
- Moderate pf (6° -20° pf) 1
- Marked pf (>20° pf) 2

**Foot Clearance in Swing (EVGS #6)**
- High steps 1
- Full clearance 0
- Reduced clearance 1
- None 2

#### Mid-Swing L

**Peak Knee Flexion in Swing (EVGS #11)**
- Severely increased (>85° flxn) 2
- Mod increased (71° -85° flxn) 1
- Normal flxn (50° -70°) 0
- Mod reduced (35° -49° flxn) 1
- Severely reduced (<35° flxn) 2

**Maximum Ankle Dorsiflexion in Swing (EVGS #7)**
- Excessive df (>30° df) 2
- Increased df (16° -30° df) 1
- Normal (15° df – 5° pf) 0
- Moderate pf (6° -20° pf) 1
- Marked pf (>20° pf) 2

**Foot Clearance in Swing (EVGS #6)**
- High steps 1
- Full clearance 0
- Reduced clearance 1
- None 2
EVGS Scoring Worksheet

Mid-Stance Front View R

Maximum Lateral Trunk Shift (EVGS #17)
- Reduced lat shift of trunk: 1
- Normal (approx 25 mm shift over stance leg): 0
- Moderate inc lat shift: 1
- Severely inc lateral shift: 2

Pelvic Obliquity (EVGS #14)
- Marked down (>10°): 2
- Mod down (1° - 10°): 1
- Normal (0° - 5° up): 0
- Mod up (6° - 15°): 1
- Marked up (>15°): 2

Knee Progression Angle (EVGS #8)
- External (part knee cap visible): 2
- External (all knee cap visible): 1
- Normal/Neutral (knee cap midline): 0
- Internal (all knee cap visible): 1
- Internal (part knee cap visible): 2

Foot Rotation/Progression Angle (EVGS #5)
- Marked ext > KPA (by > 40°): 2
- Mod ext > KPA (by 21° - 40°): 1
- Normal/Sl more ext than KPA (0° - 20°): 0
- Mod int > KPA (by 1° - 25°): 1
- Marked int > KPA (by > 25°): 2

Mid-Stance Front View L

Maximum Lateral Trunk Shift (EVGS #17)
- Reduced lat shift of trunk: 1
- Normal (approx 25 mm shift over stance leg): 0
- Moderate inc lat shift: 1
- Severely inc lateral shift: 2

Pelvic Obliquity (EVGS #14)
- Marked down (>10°): 2
- Mod down (1° - 10°): 1
- Normal (0° - 5° up): 0
- Mod up (6° - 15°): 1
- Marked up (>15°): 2

Knee Progression Angle (EVGS #8)
- External (part knee cap visible): 2
- External (all knee cap visible): 1
- Normal/Neutral (knee cap midline): 0
- Internal (all knee cap visible): 1
- Internal (part knee cap visible): 2

Foot Rotation/Progression Angle (EVGS #5)
- Marked ext > KPA (by > 40°): 2
- Mod ext > KPA (by 21° - 40°): 1
- Normal/Sl more ext than KPA (0° - 20°): 0
- Mod int > KPA (by 1° - 25°): 1
- Marked int > KPA (by > 25°): 2
**Mid-Stance Rear View R**

Hindfoot Valgus/Varus (EVGS #4)

- Severe valgus ( > 15°) 2
- Moderate valgus (6° - 15°) 1
- Normal (0° - 5° valgus) 0
- Moderate Varus (1° - 10°) 1
- Severe Varus ( > 10°) 2

**Mid-Stance Rear View L**

Hindfoot Valgus/Varus (EVGS #4)

- Severe valgus ( > 15°) 2
- Moderate valgus (6° - 15°) 1
- Normal (0° - 5° valgus) 0
- Moderate Varus (1° - 10°) 1
- Severe Varus ( > 10°) 2
Edinburgh Visual Gait Score: Summary Score Grid

<table>
<thead>
<tr>
<th>Phases of Gait Cycle</th>
<th>Joint/Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trunk</td>
</tr>
<tr>
<td></td>
<td>Right</td>
</tr>
<tr>
<td>Sagittal</td>
<td></td>
</tr>
<tr>
<td>Initial Contact (13, 10, 1)</td>
<td></td>
</tr>
<tr>
<td>Mid Stance (16, 15, 2)</td>
<td>EVGS # 16</td>
</tr>
<tr>
<td>Terminal Stance (12, 9, 3)</td>
<td></td>
</tr>
<tr>
<td>Mid Swing (11, 7, 6)</td>
<td></td>
</tr>
<tr>
<td>Coronal</td>
<td></td>
</tr>
<tr>
<td>Mid Stance front (17,14,8,5)</td>
<td></td>
</tr>
<tr>
<td>Mid Stance Back (4)</td>
<td></td>
</tr>
<tr>
<td>Segment Totals</td>
<td>0-4</td>
</tr>
<tr>
<td>Right LE Total</td>
<td>34</td>
</tr>
<tr>
<td>Left LE Total</td>
<td>34</td>
</tr>
</tbody>
</table>